

Claims

1. Method for compressing a digitally coded video frame sequence, comprising the steps of
- 5 a, dividing a given frame into blocks,
b, optionally, further dividing individual blocks into smaller blocks,
c, modifying the information content of selected blocks relying on information contained in a
neighbouring block or blocks (prediction),
d, generating transformed blocks by carrying out on the selected blocks a transformation
10 (DCT) that converts spatial representation into frequency representation, and finally
e, encoding the information content of the transformed blocks by entropy coding,
characterised by that
- 15 i, compressibility analysis is performed on said selected blocks before carrying out the
transformation specified in step d, and, depending on the result of the analysis
ii, steps c, (prediction) and d, (DCT) are carried out on the block or
iii, optionally, the block is further partitioned into sub-blocks, and the compressibility analysis
specified in step i, is performed again on the blocks resulting from individual partitioning, and
20 iv, the block partitioning that will potentially yield the best results is chosen relying on results
given by steps i and iii, and finally
v, the transformation specified in step d, is carried out using the block partitioning with the
best potential results, relying on the prediction specified in step c.
- 25 2. The method according to Claim 1, characterised by that the compressibility analysis of
blocks belonging to individual block partitionings is performed taking into account the
content of the blocks and/or the frequency of occurrence of individual block types.
- 30 3. The method according to Claim 1, characterised by that the contents of the blocks are
subjected to variance analysis either directly or by way of a Hadamard filter during the
compressibility analysis.

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4. The method according to Claim 3, characterised by that the variance is calculated using the following formula:

$$\text{variance} = \frac{\sum_{j=0}^M \text{pixel}_j^2 - \left(\sum_{j=0}^M \text{pixel}_j\right)^2}{M}$$

where M is the number of elements in the given block or sub-block and pixel(i) is an element of the uncompressed (original) block, with the computed variance value being compared with a given threshold value to establish if the variance exceeds said given threshold value.

5. The method according to any one of Claims 1-4, characterised by further encoding with the entropy coding specific data that are assigned to blocks with the maximum allowed block size in a given frame, the specific data representing the block partitioning of the block they are assigned to (Quadtree).

6. The method according to any one of Claims 1-5, characterised by that discrete cosine transform (DCT) is applied as the transformation that converts the representation in the spatial domain into a representation in the frequency domain.

7. The method according to Claim 6, characterised by that DCT is applied on blocks smaller than 16x16, and Hadamard transform is applied on blocks with a size of 16x16 pixels.

8. The method according to any one of Claims 1-7, characterised by that the information content of the modified (predicted) blocks is quantified during the compressibility analysis with the following formula:

$$\text{sum}_{(i)} = \sum_{i=0}^M \text{abs}(\text{pixel}_{(i)})^2$$

where

M is the number of elements in the predicted block, and

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pixel(i) is an element of the predicted block, with the computed "sum" value with a given threshold value or against a former "sum" value to establish if the computed "sum" value exceeds said given threshold value or said former "sum" value.

- 5 9. The method according to any one of Claims 8, characterised by that during the prediction of individual blocks prediction is carried out using multiple prediction modes, with the prediction mode yielding the lowest "sum" value being applied on the given block.
- 10 10. The method according to any one of Claims 1-9, characterised by that in case the occurrence count of individual block sizes establishes that the frequency of occurrence of the two most frequently occurring block sizes exceeds a given value, all blocks are replaced with blocks of the two most frequently occurring block sizes.
- 15 11. The method according to any one of Claims 1-10, characterised by that an error is computed during the compressibility analysis of blocks, with the blocks contributing to the error above a threshold value being divided into further sub-blocks, taking into account the computed error.
- 20 12. The method according to Claim 11, characterised by that if the error exceeds a predetermined value in case of a given sub-block, that sub-block is divided into further smaller sub-blocks and the compressibility analysis is performed on the resulting block partitioning which includes the smaller sub-blocks.
- 25 13. The method according to any one of Claims 1-12, characterised by that blocks and sub-blocks of sizes of 16x16, 8x8, 4x4 or 2x2 are used.
- 30 14. Method for compressing a digitally coded video frame sequence, comprising the steps of
a, dividing a given frame into two-dimensional blocks,
b, establishing a block partitioning of the frame, in specific cases by dividing individual blocks into further sub-blocks,

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c, carrying out on the information content of blocks a transformation (DC spatial representation into frequency representation, producing thereby transformed multiple-element two-dimensional blocks (matrices of DCT coefficients) and
 d, modifying the elements of the transformed blocks according to external boundary
 5 conditions (quantization), and finally
 e, encoding the information contained in transformed blocks by entropy coding,

characterised by that

10 in step d, the modification of the data in transformed multiple-element two-dimensional blocks is modified depending on the size of the blocks and on the bandwidth available for transmitting coded data.

15 15. The method according to Claim 14, characterised by that the modification of transformed blocks is a quantization.

16. The method according to Claim 15, characterised by that the quantisation is MPEG quantisation, according to the following function:

$$20 \quad qcoeff_{(j)} = \left(\frac{(data_{(j)} * 16) + (matrix_{(j)} * 0.5)}{matrix_{(j)}} * \left(\frac{2^{17}}{QP * 2} + 1 \right) \right) / 2^{17}$$

where

qcoeff(j) is an element of the transformed multiple-element two-dimensional block,
 matrix(j) is an element of a matrix corresponding in size to the transformed multiple-element
 25 two-dimensional block,

QP is the quantization factor.

17. The method according to Claim 16, characterised by that values of matrix(j) are taken
 from an empirically established matrix table, where individual elements of the table are entire
 30 matrix(j) matrices, with selection from said table being performed according to the external
 boundary condition specified in step d.

18. The method according to Claim 16 or 17, characterised by that selection from the table is performed with respect to the value of the QP quantization factor.
- 5 19. The method according to any one of Claims 16-18, characterised by that the entire QP domain is divided into N subdomains with matrix tables being assigned to individual subdomains, where the size of said matrix tables corresponds to the block size, with each subdomain being assigned to a previously specified bandwidth range.
- 10 20. The method according to any one of Claims 16-19, characterised by that the external boundary condition of step d, is placed by the available storage capacity and/or the available bandwidth.
- 15 21. The method according to any one of Claims 14-20, characterised by that in specific cases the information content of the selected blocks is modified prior to the transformation carried out in step c, on the basis of the information contained in previously selected image elements of a neighbouring block or blocks (prediction) or the information content of a reference block included in a reference frame.
- 20 22. The method according to any one of Claims 14-21, characterised by that for encoding intra frames steps of the method according to any one of Claims 1-13 are also carried out.
- 25 23. Method for compressing a digitally coded video frame sequence, where the information content of certain frames is encoded from the contents of the preceding or subsequent frames (reference frames), the method further comprising the steps of
- 30 a, dividing the frame to be encoded into blocks,
b, searching a matching reference block for the given block to be encoded in the reference image preceding or following the frame containing said block to be encoded,
c, carrying out a compressibility analysis by comparing matched reference blocks and the block to be encoded,
d, selecting the best reference block relying on the result of the compressibility analysis, and
e, encoding said block using the best reference block just selected,

characterised by that in step b, during the search for reference blocks

- i) the block to be encoded is divided into sub-blocks,
 - 5 ii) the contents of the sub-blocks are analysed,
 - iii) according to pre-defined criteria, a predetermined number of sub-blocks, preferably at least two, are selected,
 - iv) a reference block search is performed using the selected sub-blocks, said search being performed in a specific search range in the selected reference frame for the reference block
 - 10 containing sub-blocks that differ the least from the selected sub-blocks, with the relative position of the selected blocks kept constant during said search, and
 - v) the best reference block is chosen as a result of a search using the selected sub-blocks.
24. The method according to Claim 23, characterised by that in step v) the best reference
- 15 block is chosen in such a way that every time the search finds a block that is better than the current reference block, position data of the newly found block are written into a multiple-element circular buffer, with the last element of the buffer containing the position of the best sub-block.
25. The method according to Claims 23 or 24, characterised by that a reference search is
- 20 carried out using the entire block to be coded, and the search being performed in the vicinity of the reference block that is considered as the best reference block, and the final reference block is chosen according to the result of said search performed using the entire block to be coded.
26. The method according to any one of Claims 23-25, characterised by determining the
- 25 absolute square difference of the block to be coded and the reference block, and deciding about the acceptability of the reference block on the basis of the determined difference.
27. The method according to any one of Claims 23-26, characterised by that the reference
- 0 block search is performed in a filtered reference frame.

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28. The method according to any one of Claims 23-27, characterised by that if the search results are still not satisfactory, reference block search is carried out in search ranges located in further reference frames.

29. The method according to any one of Claims 23-28, characterised by that in case the search is unsuccessful in all reference frames, the block to be coded is divided into sub-blocks, with a matching reference sub-block being searched for for each sub-block, said search being performed in the vicinity of the reference frame positions that are considered the best, in that reference frame which has so far yielded the best results.

30. The method according to Claim 29, characterised by that in case dividing the block to be coded into sub-blocks has not produced satisfactory results, the search for reference sub-blocks is carried on in the vicinity of the best positions of other reference frames.

31. The method according to Claim 29 or 30, characterised by that in case a sub-block remained erroneous, the erroneous sub-block is further divided into smaller sub-blocks, and the search is repeated.

32. The method according to any one of Claims 23-31, characterised by that the block to be coded is subtracted from the reference block, and the difference block is encoded in step e.

33. The method according to any one of Claims 23-32, characterised by carrying out on the information content of the difference block a transformation (DCT or Hadamard transform) that converts spatial representation into frequency representation, producing thereby transformed multiple-element two-dimensional blocks (matrices of DCT or Hadamard coefficients), and encoding the information content of the transformed blocks by entropy coding.

34. The method according to any one of Claims 23-32, characterised by that steps of the method according to any one of Claims 1-13 are also carried out during the process of encoding.

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35. Method for compressing a digitally coded video frame sequence, comprising

a, dividing each frame into blocks that are to be separately coded,

b, carrying out on the information content of the blocks a transformation (DCT) that converts spatial representation into frequency representation, producing thereby transformed blocks,

5 and finally

e, encoding the information contained in transformed blocks by entropy coding, and applying arithmetic coding as entropy coding, during which

- a bit sequence is encoded by modifying the lower and upper limit of an interval as a function of values of consecutive bits of the bit sequence, and

10 - the distribution of the already arrived bits of the sequence is taken into account in the function that modifies the limits of said interval,

characterised by that

15 - addresses are generated from already arrived bit values of the bit sequence,

- said addresses are applied for addressing individual processing elements of a neural network comprising multiple processing elements, and

- parameters of the processing element are modified such that the frequency of individual addressing operations and the value of the currently arriving bit of the bit sequence are used

20 as input data, and the output of the neural network is applied for determining a parameter that modifies the lower or upper limit the interval,

- after an initial learning phase involving the processing of multiple bits, the upper or lower limits of the interval being determined during the encoding of incoming bits as a function of the output of the neural network.

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36. The method according to Claim 35, characterised by that the incoming bit sequence to be encoded is fed into a buffer, and divided into multiple shorter bit sequences.

37. The method according to Claim 36, characterised by that the binary value represented by
30 the bits of the shorter bit sequences is regarded as an address.

38. The method according to any one of Claims 35-37, characterised by that the method is used for selecting rows of a table, where said table contains function values representing the frequencies of occurrence of the possible values of the current bit to be coded, as well as at least one weight function.

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39. The method according to Claim 38, characterised by that the weight functions of individual neurons are modified as a function of the function values representing the occurrence frequencies of the potential values of the bit to be coded.

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40. The method according to Claim 35, characterised by that potential address ranges of the addresses form unions with one another (are at least partially overlapping);

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41. The method according to any one of Claims 35-40, characterised by that the gain and the learning rate of the neural network are dynamically adjusted according to the boundary conditions.

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42. The method according to any one of Claims 35-41, characterised by that the encoder is used with different levels, where parameters of each level can be adjusted separately, with a neural network operating with dedicated parameters being assigned to each level.

43. The method according to any one of Claims 35-42, characterised by that steps of the method according to any one of Claims 1-34 are also carried out during the process of encoding.

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44. Method for compressing a digitally coded video frame sequence, comprising the steps of
a, dividing a given frame into two-dimensional blocks,

b, carrying out on the information content of blocks a transformation (DCT) that converts spatial representation into frequency representation, producing thereby transformed multiple-element two-dimensional blocks (matrices of DCT coefficients) and

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c, modifying the elements of the transformed blocks according to external boundary conditions (quantization), and finally

d, encoding the information contained in transformed blocks by entropy coding,

characterised by that

modification of the data of the transformed multiple-element two-dimensional blocks is
5 carried out in step c, as a function of the output of a neural network.

45. The method according to Claim 44, characterised by that the neural network has
backpropagation or counterpropagation structure, or is a simple network composed of
multiple neurons, where

- 10 - the normalized values of expected/coded length and expected/coded quality are used as input
data,
- a specific number of previously received input data and the current input data are stored in a
time window (time slot), with the data contained in the time window (slot) being assigned to
the input neurons of the neural network.

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46. The method according to Claim 45, characterised by that the number of neurons in the
input layer of the network equals the number of data elements stored in the time window.

20 47. The method according to Claim 46, characterised by that the network comprises a hidden
layer.

48. The method according to Claim 47, characterised by that the number of neurons in the
hidden layer is larger than the number of neurons in the input layer.

- 25 49. The method according to Claim 44, characterised by that the normalized expected/coded
length values and expected/coded quality values are applied as input data,
- a predetermined number (N) of previously received input data elements (preferably N=31 or
N=63) are stored in a time window together with the current input data, and generating
addresses based on the data contained in the time slot,
30 - input data are rounded off to a given bit length for the address generation process,

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- an address is generated from each element of the time window by means of said address pointing to an element of a table corresponding to one of the processing elements of the network.

5 50. The method according to Claim 49, characterised by that the network is pre-trained utilizing the expected/coded length and quality data in their original form, before they are rounded off for address generation.

10 51. The method according to Claims 49 or 50, characterised by that addresses are generated by means of a hash function from the data contained in the time window.

52. The method according to any one of Claims 44-51, characterised by that the minimum and maximum allowed bandwidth values are applied as input data for two processing elements that are independent from the rest of the network.

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53. The method according to Claim 52, characterised by that results generated by the processing elements of the network and the two independent processing elements appear at two outputs.

20 54. The method according to Claim 52, characterised by that the output of the neural network is a frame size scaling factor and/or a quantization factor.

55. The method according to Claim 52, characterised by that the output of the neural network is a frame size scaling factor and/or a quantization factor.

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56 The method according to any one of Claims 44-55, characterised by that steps of the method according to any one of Claims 1-43 are also carried out during the coding process.

30 57. Apparatus for encoding digital video data, characterised by that it comprises means adapted for performing the steps of the method according to any one of Claims 1-55.

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58. Software containing instructions for carrying out the steps of the method of Claims 1-55.

59. Coded sequence produced by the compression method according to any one of Claims 1-55.

60. Method for decompressing encoded video data from a coded sequence produced by the compression method according to any one of Claims 1-55.